

Final Report of Joint Research Interchange NCC2-5081

Funding from this Joint Research Interchange was used to begin studies that will lead to an analysis of control of linear vestibulo-ocular reflexes by specific groups of vestibular-nerve afferents. We investigated three-dimensional eye movements evoked by unilateral labyrinthine galvanic polarizations in the squirrel monkey. A publication has resulted from these studies (Minor et al. 1997; copy enclosed).

Experiments were performed in three squirrel monkeys. Each monkey was implanted with a head restraining bolt and with three scleral search coils for recording eye movements. A frontal coil (for transducing horizontal and vertical eye movements) was implanted on both the right and the left eye. A sagittal coil (for transducing torsional eye movements) was implanted laterally on the right eye. Testing was performed in the Vestibular Research Facility at the NASA Ames Research Center. The animal was seated in a primate chair in the upright position with the horizontal canals aligned in the earth-horizontal plane during testing. The primate chair was placed in a magnetic field coil assembly (CNC Engineering).

Labyrinthine stimulating electrodes were implanted in the right and left ears of each animal. A chlorided silver wire was fit through a hold in the bony promontory of the middle ear and inserted into the perilymphatic space of the vestibule. A second chlorided silver wire was placed in the hypotympanum. Constant DC currents, typically 5 – 8 sec duration, were delivered by a stimulus isolator (A-M Systems) and monitored with an in-series digital ammeter. Currents are designated as cathodal (excitatory) or anodal (inhibitory) to indicate polarity of the perilymphatic electrode.

A horizontal, torsional nystagmus was evoked by the unilateral galvanic polarizations. A vertical component of lower and more variable slow phase velocity was occasionally present. Cathodal stimulation in the right ear resulted in slow phases directed to the left and counterclockwise (with respect to the animal, corresponding to intorsion of the right eye). Mean horizontal and torsional eye velocity for 100 μ A cathodal polarizations were 26.5 ± 8.9 and 29.0 ± 10.1 deg/sec, respectively. Mean horizontal and torsional eye velocity for 100 μ A anodal polarizations were 17.7 ± 5.8 and 15.7 ± 3.8 deg/sec, respectively.

Examination of nystagmus evoked by unilateral currents less than 100 μ A revealed clear differences in the profiles of horizontal and torsional slow phases. Horizontal slow phases were relatively linear whereas torsional ones showed a decay of slow phase velocity that could be approximated by a single exponential. The time constant of this exponential decay in each torsional slow phase evaluated for 50 and 75 μ A cathodal and anodal stimulation in two animals measured 259 ± 73 msec (mean \pm s.d.). The third animal had a longer time constant of 382 ± 49 msec (t-test, $p < .05$).

Torsional responses typically showed declining eye velocity during administration of current followed by an after-response in the opposite direction. This profile of perstimulus response decline followed by an after-response in the opposite direction after

cessation of current was present for torsional responses evoked by anodal and cathodal stimuli.

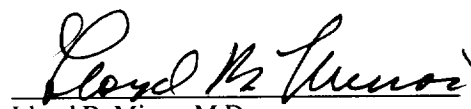
The three-dimensional characteristics of eye movements evoked by unilateral galvanic polarizations can be predicted based upon the currents affecting each ampullary nerve relatively equally. Both the anterior and posterior canals contribute to the torsional response. Thus, torsional eye velocity evoked by polarization is relatively equal to horizontal even though the gain of the torsional VOR is $\frac{1}{2}$ that of the horizontal VOR.

The decline in torsional slow phase eye velocity that is reset by each fast phase is reminiscent of eye movements occurring when the velocity-to-position integrator has been made leaky. Such an exponential decay in slow phase eye velocity is more obvious at lower current strengths because the duration of slow phases is longer and the velocity decay is more obvious. This finding is consistent with results of other studies showing that the time constant of the torsional velocity-to-position integrator, measured from position-step displacements of the eye, is approximately 2 sec whereas that of the horizontal velocity-to-position integrator is > 20 sec.

Torsional slow phase velocity during stimulation typically reached a peak within 500 msec after stimulus onset and then declined during the following 4 – 8 sec of current administration. An after-response in the opposite direction was frequently noted immediately after the current was turned off. These responses were modeled with an adaptation operator. Adaptation is representative of two processes. Vestibular-nerve afferents show adaptation to prolonged acceleration steps manifested as per-acceleration response decline and post-acceleration response reversal prior to return to resting activity. Central adaptation processes have been suggested based upon the observed reversal phases of both postrotatory nystagmus and optokinetic afternystagmus.

Publication resulting from this JRI:

Minor, L.B., Tomko, D.L., and Paige, G.D. (1997) Torsional eye movements evoked by unilateral labyrinthine galvanic polarizations in the squirrel monkey. In: Fetter, M., Haslwanter, T., Misslisch, H., and Tweed, D. (eds.) Three-Dimensional Kinematics of Eye, Head and Limb Movements. Amsterdam: Harwood Academic Publishers, pp. 161-170.



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